

AUTOMATED SYSTEM FOR AIRLINE OPERATION MONITORING: AN INSIGHT INTO AIRLINE PERFORMANCE AND ECONOMICS

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Abstract: The purpose of the paper is to bring out the capability of the NALFOQA tool to Indian Aviation sector in terms of airline performance and Economics. The tool utilizes the Digital Flight Data Recorder (DFDR) or Quick Access Recorder (QAR) Data for analysis. The Digital data is decompressed, analyzed and converted to engineering units for monitoring, generating Trend, generating Report, or replaying the animated flight in 3D. Based on the analysis of the data the airline takes action accordingly to improve the crew performance, aircraft operating procedures, aircraft maintenance and economics. Although FOQA programs are primarily viewed as a safety program, Indian and foreign airlines using FOQA tool, have reported financial benefits as well. With additional data on aircraft systems and engine conditions, airlines are better able to achieve optimum fuel consumption and avoid unneeded engine maintenance. NALFOQA as a tool has been used at various Flight Safety stations of different Indian Operators to enhance safety over time, lower insurance premiums, and improved overall crew performance. Major airlines in India, as well as the office of the Director General of Civil Aviation (DGCA), who are using NALFOQA, are uniform in their support of the program. NALFOQA offers integrated solutions for managing safe and cost-effective flight operations – a requirement that is more important than ever before.

Keywords: Airline performance and Economics, DFDR data, FOQA, Quality Assurance

Introduction and Motivation:

In today's market, profit margins of most airlines are under permanent pressure. Fierce competition and impact of fuel prices emphasize the significance of operational efficiency. National Aerospace Laboratory's (NAL) Flight Operation and Quality Assurance (FOQA) tool, known as NALFOQA [1], developed in-house has helped in improving Airlines performance and Economics. The objective of NALFOQA is to use flight data to detect technical flaws, unsafe practices, or conditions outside of desired operating procedures early enough to allow timely intervention to avert accidents or incidents. The dramatic growth in air travel which has occurred over the past several years has placed a severe burden on air traffic control and airport facilities. While the Civil aviation authorities of India are working hard to upgrade its facilities and train more air traffic controllers, air travelers continue to face increasing delays in both number and duration. In view of this tool like NALFOQA has helped a lot to airlines sector in terms of improving their overall crew performance and better Economy saving.

Performance and Economics of a typical Civil Airline sector:

The airline industry is a very particular system. Airlines provide a service, which is to transport a passenger between two cities at an agreed price. There is neither physical product given to the consumer, nor inventory created and stored. Airlines also exhibit very particular economics that, over time, have motivated specific management concepts, tools and practices. The industry is capital intensive but also labor intensive. The setup costs for an airline are huge (airplanes, hangars, flight simulators) and most capital is financed through loans. In addition, airlines employ many people (from pilots to baggage handlers, from cooks to lawyers). The airline industry is a complex system tackled at different levels or scales. Within the industry, an airline is itself a system. Its organic picture reflects the combination of functions assembled together to produce a final and unique output. A very high-level functional chart of an airline is shown in **Error! Reference source not found.**

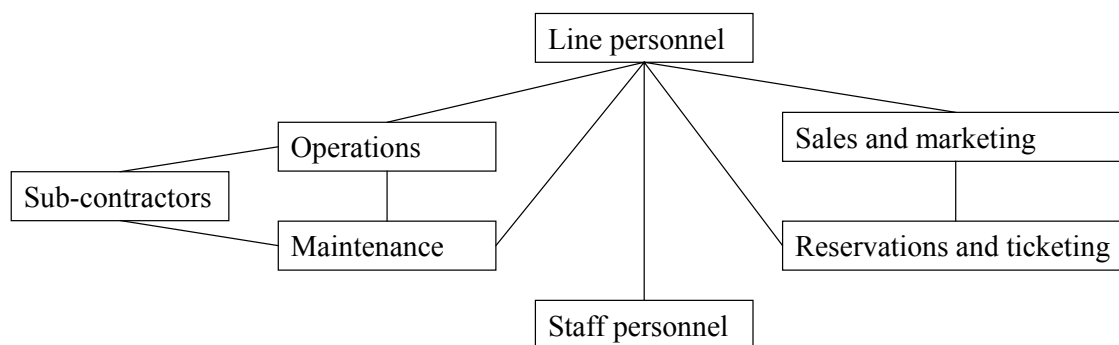


Figure 1: Functional chart of an airline

In the figure, Line Personnel includes every person related to operating a flight, that is, mechanics, pilots, reservation clerks, airport and gate personnel, ramp-service agents and security guards. Typical sub-contracted services include cleaning, fueling, security, food and maintenance. Explicitly introducing and considering sub-contracting acknowledges the existence of a system surrounding the airline industry and inter-industry interactions. In other words, the airline is put into a context, a web of interacting industries. Consequently, it may be less expensive to acquire services from other industries than having people able to perform every single task. It can be clearly cited that the overall performance of aircraft depends on so many factors. Profit margins are seasonal and thin. The net profit of an airline is between 1 and 2%. It increases in the summer, when most people take vacations, and decreases during winter (except for holidays). Demand for air transport clearly presents peaks and valleys. Airlines deal with this by shifting customers across the year using discounts and promotions (e.g. double air miles during winter). Airlines' revenues come primarily from passengers (75% passengers, 15% cargo shippers). Most of the revenue associates with passengers (around 80%) come from domestic travel. Travel agencies, with computer-based reservation systems, are paramount in ticket sales. They account for 80% of the tickets issued. Note that travel agencies are elements outside the airline itself that have a huge impact on the economics of the system. Therefore, when drawing the boundary of the airline industry, one has to take them into account. The management tools employed in the industry include general principles applied to very particular concepts of an airline. For example, a very useful indicator is the break-even load factor, which in the context of this industry means the percentage of seats that an airline has to sell to cover its costs. This is usually around 66%.

Airlines operate near this margin and 1 or 2 seats in a flight can make the difference between profit and loss. Other issue carefully analyzed in the industry is seat configurations. More seats in an airplane entail more revenue at the same cost, but also less comfort for passengers. The best strategy is to analyze the market for each flight and check what passengers prefer. If they value lower price tickets, use a plane with more seats. If they belong to a business community, use a plane with fewer seats (pricing higher), but that gives them more comfort and workspace. Another strategy commonly used by airlines is overbooking, which occurs when there are more passengers for a flight than seats available. Overbooking is done carefully and is based on the observed past behavior of passengers, which allow the airline to be sure that a certain number of passengers will, most likely, not show up to a particular flight. Finally, pricing and scheduling are also two major, very complex, tasks that an airline must perform. Pricing is purely competitive since deregulation of the industry. Each ticket is sold according to the value that the passenger gives to having a seat in a particular flight. The goal of the airline is to maximize its revenue in each flight (because the cost associated with a particular flight is pretty much fixed) offering the correct mix of tickets (full-fare, discounted, upgraded). This is a complex optimization process, accomplished today by specific computer software. Scheduling is also free since the late 1970s. It is also obtained using powerful computer software that takes into account demand, crew availability, maintenance, airport restrictions and aircrafts.

Factors influencing performance and analysis of Airlines:

Increases in automation may help to some extent, however, simply continuing to increase the degree of automated assistance is not a universal panacea in increasing operating efficiency. probably suggested that automation offers benefits in four basic areas: safety; reliability; economy and comfort. In the context of civil aviation “Performance and efficiency” is most often, either directly or indirectly, related to cost; “waste” refers to a waste of time or money. Good human factors will not significantly increase performance by itself. On its own, only small incremental gains may be made. A wider, sociotechnical perspective needs to be adopted before any true performance and efficiency gains incorporating good human factors can be realized. The operation of an airliner is not just about the integration of pilot (human) and aircraft (machine) to perform a flight (or mission) within the constraints imposed by the physical environment (medium). This approach needs extending to encompass the societal environment, an additional aspect of the medium. The role of management is also central to safety and efficiency. Designers and engineers must not only work within the bounds of the technology, the capabilities of the end-users and the physical aspects of the medium, but they must also abide by the rules and norms of society (the societal medium). The performance standards for human-machine systems are primarily determined by societal norms (regulations), e.g. the level of redundancy required (aircraft certification) or minimum standards of user competence (flight crew licensing). The prime drivers to enhancing operational performance in the last decade have been the low-cost carriers. These operators now command a significant proportion of the market and have been responsible for the larger airlines having to achieve increases in efficiency to remain competitive. An aircraft on the ground is both failing to generate revenue and is also costing the airline money as airport gates are charged by the minute. In terms of Economy performance it is beneficial to minimise this time, something the low cost operators have been successful in achieving. However, a broader perspective needs to be taken, which influences both airline safety and efficiency.

High levels of efficiency in low-cost airlines require that crews are utilised to the maximum but without resulting in stress and fatigue, which may result in Incident or accident. In recent years, incidences of stress and depression have begun to increase as a result of factors such as worries about company stability and large numbers of last minute flying schedule changes, which are common as a result of crew being used more “efficiently” All of these factors represent an increase in operational efficiency. The fallacious argument that safety can be improved by removing the operator from the system, thereby avoiding error, must be avoided. There are three problems with this approach. Firstly, automated devices are designed and built by human beings (just the nature of error changes). Secondly, such devices are not perfect and have the potential for generating errors. Thirdly, a highly trained individual who understands the automation is required to monitor and intervene when automation parameters are exceeded or an unexpected event in the operating environment occurs. Human intervention is required In terms of economy and reliability the autothrottle and autopilot can fly the aircraft more smoothly, accurately and economically than a pilot. They adapt to environmental disturbances faster and can fly complex thrust management schedules. As a result, aircraft can be operated more economically under autoflight control and can function more smoothly, producing less “wear and tear” thereby reducing maintenance costs. Furthermore, the onboard sensors and automation allow for more precise control and navigation allowing shorter flying times, and hence increasing efficiency. In

some sections of airspace vertical separations are being reduced to 1,000 ft and in free flight

area aircraft are required to self assure in-trail separations.

Firstly, the operating regulations require a minimum of two qualified flight deck crew (Code of Federal Regulations, Title 14; *Joint Airworthiness Requirement – Operations (JAR-OPS)*). Until the regulations are changed, no matter how highly automated the aircraft is, the airline will still be required to place two highly qualified, highly paid pilots on the flight deck. Secondly, many departure and arrival air traffic control procedures still cannot exploit the automation available in modern aircraft. This is as a result of such factors as the arrangement of the airspace near the airport, air traffic procedures not congruent with the automaton and/or a lack of knowledge on the part of air traffic controllers about utilising the capabilities of a modern flight management system to best effect. As a result, the flight crew have to semi-manually “fly” the aircraft and most automation is not particularly “efficient” in these circumstances.

Use of NALFOQA in improving the performance and Economics of Airlines:

NALs Flight Operation Qulaity Assurance (NALFOQA) offers a wide range of services to insure smooth, efficient and safe flight operations. They focus on improving flight performance by maximizing each individual flight’s payload, while reducing fuel consumption, and optimizing aircraft utilization. NALFOQA provides capabilities of FOQA, including the capability of analyzing all the data collected, in addition to merely identifying “exceedances”. The reason why the aircraft accident rate has stayed fairly flat since the mid-70’ has caused many to speculate as to why. First of all, - is it at an acceptable level? Or is “Zero Accidents” an attainable goal to strive for. If we look back the history of civil aviation operations, there has been a remarkable developments in terms of technology change from 1970’s to current day and at the same time the airspace operations also has increased

tremendously with various kinds of airplanes and systems. Present day concepts of Integrated Aircraft Monitoring Systems (IAMS) plays a very important role in monitoring and processing of various levels of aircraft data online and offline. FAA advisory FAA AC 120-82 [7] provides the base for the FOQA functionalities and responsibilities in terms of operation and importance. Close monitoring of aircraft flight operations and systems has made continuous refinement of reliable designs and increased performance. Enabling this operational monitoring has been the continual development of even more sophisticated data recording analysis with growing capabilities to handle huge amount of raw data. Feedback into engineering and maintenance processes and into crew training has raised safety levels. Coupled with accident investigation information, operational data extracted from the flight data recorder have made it possible to refine the air transport operation to a very high standards of efficiency, while at the same time, reducing accident risk exposure. The FOQA (Flight Operational Quality Assurance) developed from flight safety foundation (FSF) studies, is being adopted by many airlines throughout the world as an internal system of operations monitoring.

FOQA data can reveal

- If an airline's trends are out of the norm
- If anomaly is an isolated occurrence or one that has been previously detected by another carrier who may have already developed a solution.
- If occurrence is a significant event that requires prompt decision- making and actions when combined with historical data
- Allow the confirmation of problem areas identified by flight crews through voluntary safety reporting programs
- Flight training
- Airline safety improvement
- Human factors study
- Operational procedures review.

And many more safety, quality and trend features of each aircraft, airlines as whole.

NALFOQA is being used at airlines for variety of aircrafts from Boeing and Airbus industry covering 64, 128,256 and 384 words per second format. It has proved to be one of the best tools for aircraft integrated data monitoring and analysis system. The software is designed to be an universal tool which can be easily configured for any aircraft with the characteristics of aircraft is known in terms of the Digital Flight Data Recorder (DFDR) / Solid State Flight Data Recorder (SSFDR) parameter specifications. The tool can be used as

- Aircraft integrated data monitoring and analysis system
- Incident / Accident analysis and report generation tool
- Aircraft performance monitoring system
- Pilots operations and quality monitoring and evaluation system
- Airlines statistics management system
- Post flight analysis and counseling tool
- Airlines efficiency management system
- Operations and quality control and management system
- Incident and accident analysis

Analysis of Airline data using NALFOQA:

NALFOQA is window-based software with database support. Database forms the base for all the trend analysis system with lot of information processed and archived. The software needs to be equipped /configured for the aircraft behavior in terms of the parameter details, phase limits and event limits. The Sequence of operations to be carried out is

- Aircraft/Configuration creation
- Parameter Configuration
- Phase Configuration
- Event Configuration
- Airlines fleet cycle configuration

Aircraft Configuration

Any new aircraft or a different configuration of the old aircraft needs to be configured into the NALFOQA for further use and reference.

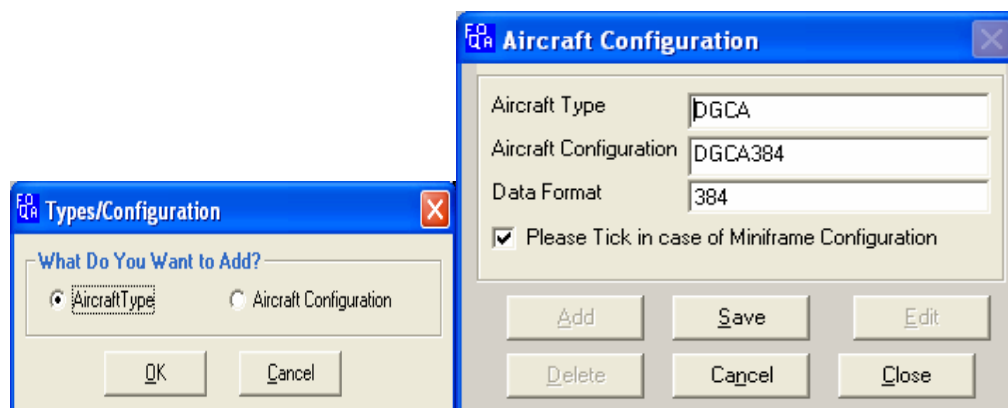


Figure 2: Aircraft Configuration in NALFOQA

Aircraft and its configuration form the basis for all the subsequent operations of incident/accident/operations analysis as part of the Aircraft Information Management System (AIMS). NALFOQA has the provision to have database facilities for the configuration [2]. The configuration menu of NALFOQA is as shown in **Error! Reference source not found..** NALFOQA can be used to configure any aircraft and start using it for analysis and has no limitations for decoding and analysis. The configuration depends on number of frames, sub-frames, mini-frames and format of recording like 64, 128, 256, 384 words/sec etc,. This will be derived from the Aircraft Maintenance Manuals (AMM)[3][4] of respective aircraft.

Parameter Configuration

Digital Flight Data Recorder records data from various sub-systems of the aircraft. The parameters so recorded falls into different types of signals, varied operating range, different resolution, varying recording bit occupancy for each parameter and the same signature need to be fed to the NALFOQA to understand the aircraft parameters for further analysis. The configuration of parameters in NALFOQA is exercised with special security password to protect the integrity of the database. The parameter configuration user interface of NALFOQA is shown in **Error! Reference source not found..** Synchronization words (SYNC) are the main known pattern words in each sub-frame to identify the state of the sub frame.

Parameter Description

Parameter: COMPUTED AIRSPEED
 Alias Name: CAS
 Display Type: Integer
 Derived: ☐
 Datatype: Binary
 Sign Status: ☐ Signed ☒ Unsigned
 Units: KNOTS
 Min Value: 30
 Max Value: 450

Matrix/TCAS: ☐
 Sticky Bit: ☐

Frame Specification
 Superframe: ☐
 Word No: 253
 Subframe: 1 2 3 4
 Miniframe: 1 2 3 4 5 6

Start Bit: 12
 Stop Bit: 0
 Data Bits: 12

Aircraft Name: A319 Aircraft Sub Type: A319-256 Data Format: 256

Figure 3: Parameter Configurations in NALFOQA

Phase Configuration

To investigate the incident for specific time of flight in terms of flight phases, the NALFOQA need to be configured for the cutting limits of various phases of the specific aircraft family. The investigation will be carried out with reference to the configured phases only.

Event Configuration

An event is an exceedence of a parameter or a set of parameters constituting the functionality of the aircraft scenario in specified conditions deviating the norms. Each event has a set of limits to be checked during the event detection process. The Event configuration parameters are defined based on the dynamics of the aircraft and its behavior. The event configuration window is as shown in Figure 4.

Configuring Event Parameters

PhaseFlags
☐ EngineStartFlag ☐ TaxiOutFlag ☐ TakeOffRollFlag ☐ TakeOffFlag ☐ ClimbFlag ☐ CruiseFlag
☒ DescentFlag ☐ Landing ☐ LandingRollFlag ☐ TaxiInFlag ☐ ParkingFlag ☐ EngineOffFlag

Event Parameters

Parameter	Operator	Value	Const	LogCond	Operator	Value	Const	LinkCond
SLAT ACTU POS TRANS VAL OF S	>=	17	NIL	AND	<=	19	NIL	AND
FLAP POSITION	>=	10	NIL	AND	<	15	NIL	AND
COMPUTED AIRSPEED	>=	215	NIL	NIL	NIL	0	NIL	NIL

LinkCond Parameter Name Operator1 Value1 Const1 LogCond Operator2 Value2 Const2
 AND SLAT ACTU POS TRANS VAL OF S >= 17 AND <= 19 0

Time: 5 Seconds

Severity Level
☒ Parameter ☐ Time
 Severity Level Limits

Buttons: Edit Time/Flags/SevLev, Add, Save, Cancel, Edit Event Parameters, DeleteAll, Delete, Close

Aircraft type: A319 Aircraft Sub Type: A319-256 EventCode: E03b

Figure 4: Event Configuration system of NALFOQA

Parameter, event and phase configuration of NALFOQA completes the configuration activity and is ready for incident/accident analysis activity. The various analysis reports and methods are listed below

- Trend Analysis
- Event Rate Analysis
- Operation Report
- Counseling Report

Each of the analysis and the resulting report are being exhaustively used at various airlines for operations and incident/accident analysis point of view. Benchmark figure of NALFOQA for 200 hours of flight data is less than 90 seconds for complete analysis.

Data Processing

The aircraft downloaded data [5] directly from the DFDR is fed to NALFOQA for data processing and analysis. The data processing facility and its output as consolidated result of NALFOQA is as shown in Figure 5.

S.No	Rel-Time	Flight	A/C Regn	Date	FltNo	GMT	Weight	AirTime	Station
1	00:38:03 TOFF	VT-SCA	01/31/07	606	08:28:53	70	01:46:48	VIDP	
1	02:24:51 TDOWN	VT-SCA	01/31/07		10:15:41	65		VABB	
2	03:16:32 TOFF	VT-SCA	01/31/07	658	12:05:45	70	01:28:32	VABB	
2	04:45:04 TDOWN	VT-SCA	01/31/07		13:34:17	65		VIDP	
3	05:19:29 TOFF	VT-SCA	01/31/07	602	15:04:49	71	01:51:16	VIDP	
3	07:10:47 TDOWN	VT-SCA	01/31/07		16:56:05	66		VABB	
4	07:59:59 TOFF	VT-SCA	02/01/07	601	00:46:22	71	01:31:44	VABB	

Figure 5: NALFOQA Aircraft Integrated Data Processing System

The first level of analysis reports the basic information, which will aid for further analysis. Event detection and monitoring is the most important activity of the analysis system with the event monitoring report for the full length of flight data or for each sector separately. A typical event report is as shown in Figure 6. Each event in the event monitoring report in Figure 6 is reviewed and checked for its reality and the severity-persistence in terms of the time and limit value. The entire processed data is stored into the master database for all statistical report generation.

Event Monitoring, detection and analysis

Crucial phase of FOQA is the event monitoring and analysis. NALFOQA provides an efficient methodology for the event analysis.

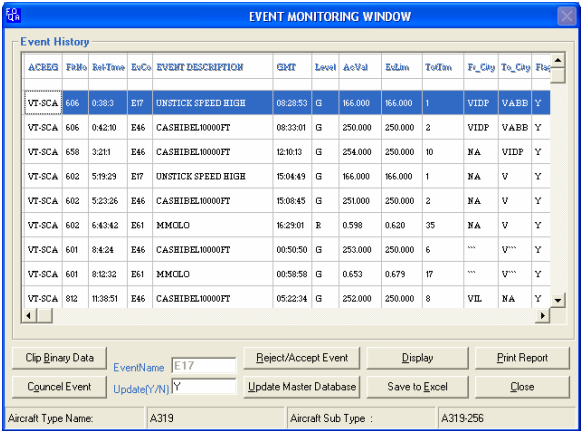


Figure 6 Typical Event Report used for incident analysis

Once NALFOQA detects the events, the event needs to be thoroughly analyzed before the event is marked for tracking. This is done in many ways, however the software provides graphical and alphanumeric displays for validation of events as shown in Figure 7.

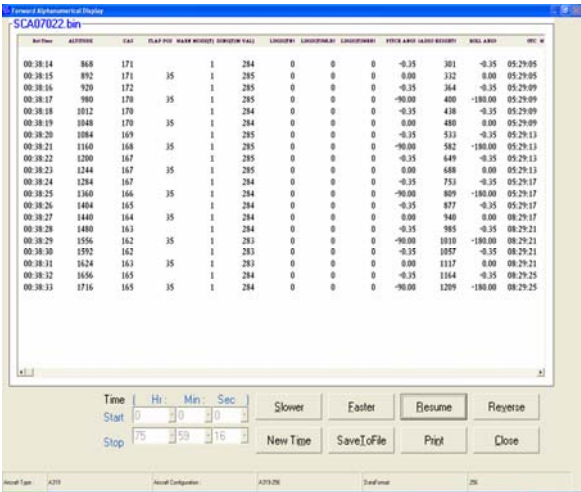
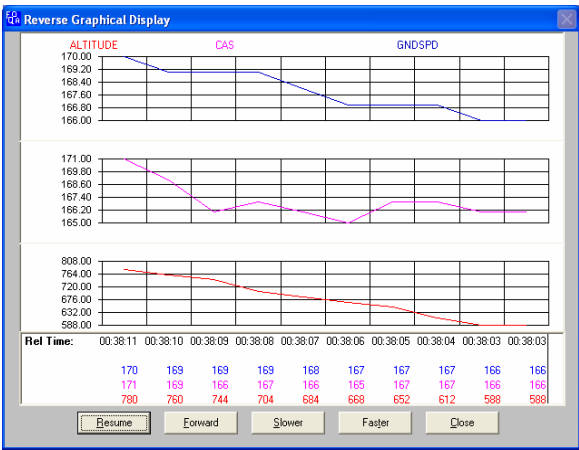


Figure 7 Event analysis graphical and alphanumeric displays of NALFOQA

1.1 Report and statistics management

NALFOQA provides number of statistical and operational reports catering to various levels of requirement from airworthiness to Engineering requirement. Typical Trend Analysis report and Event rate report are as shown in Figure 8 and **Error! Reference source not found.** respectively.

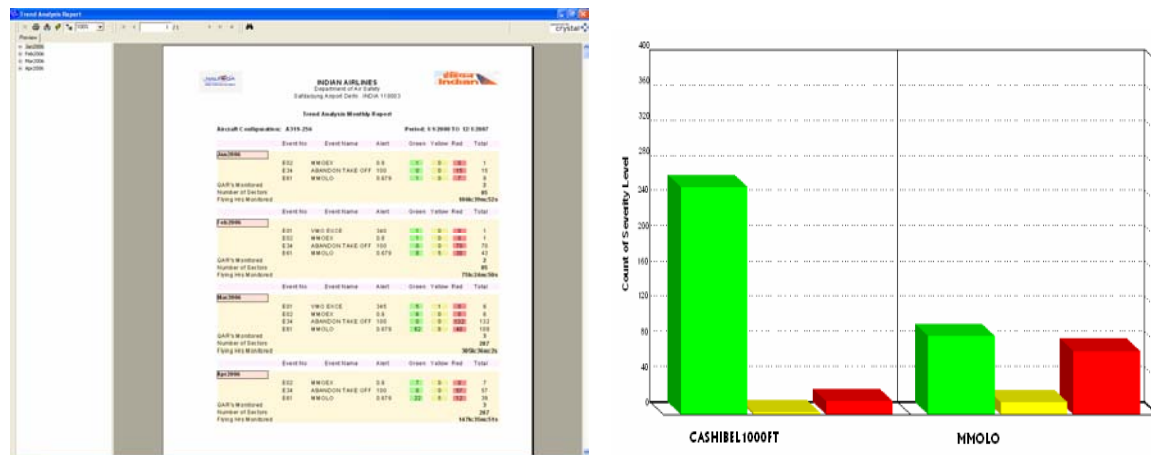


Figure 8 Monthly trend analysis report and Event rate report of NALFOQA

Similarly the reports module of NALFOQA has the following major reports apart from other routine analysis reports

- Event rate report
- Trend rate report
- Trend analysis report
- Counseling Report
- Daily, monthly, quarterly, half yearly and yearly report

Results of all reports and data analyzed are validated against the FDAU specifications for SARAS [6].

Result:

Following are the two case studies [8] done using NALFOQA for one of the flights used in India. NALFOQA software has built in capability to detect the incidents either in 2D view or 3D view. The corresponding engineering value can be displayed and can be exported to any where user wants and finally the print of those incidents can also be taken. Following are the two case study using NALFOQA software.

Figure 10

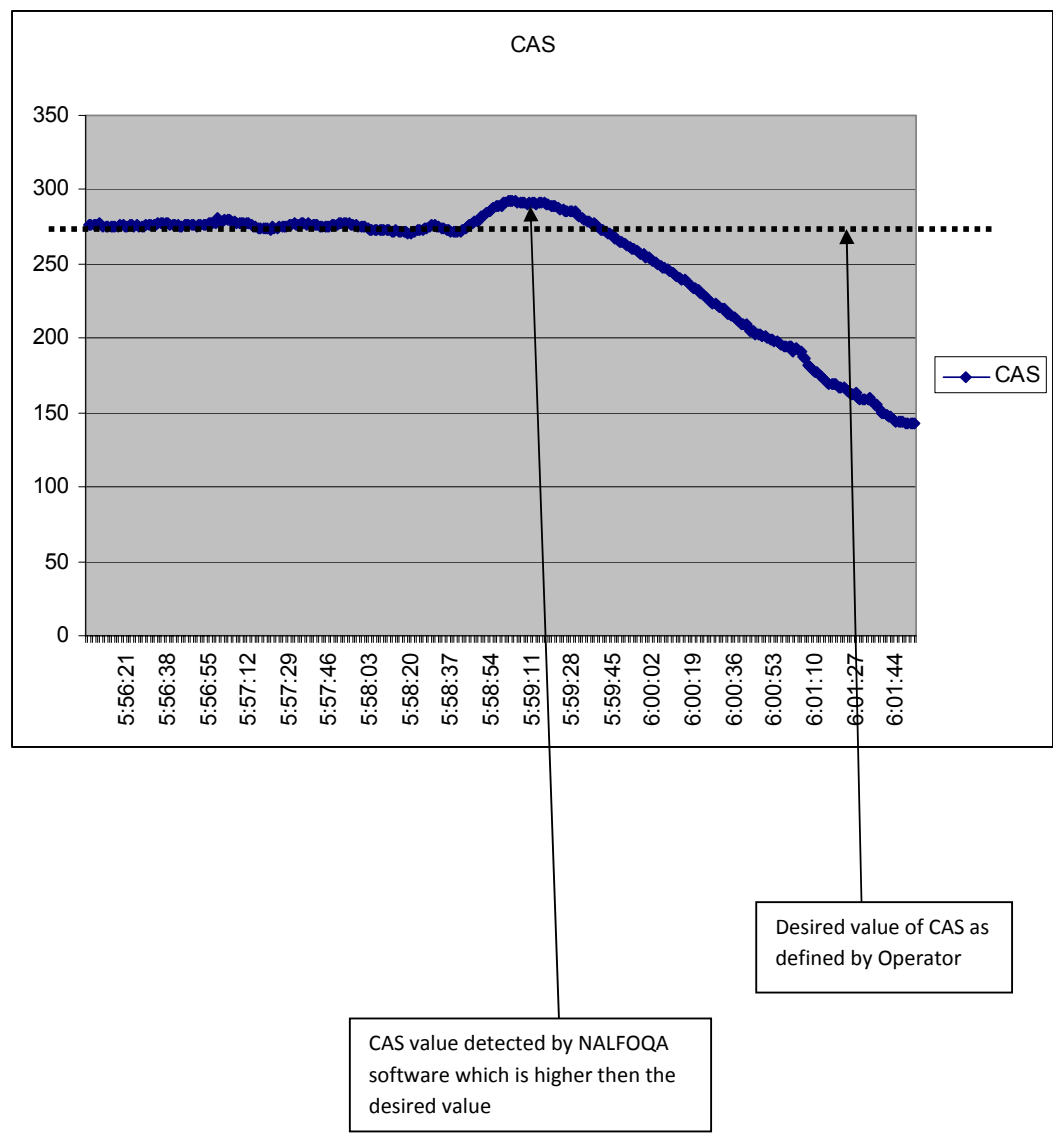


Figure 10: CAS HI event for ALT les then 100000 ft

Conclusion:

Airline safety is more important than ever before, because we rely on air commerce for so much of our global economy. And yet aviation disasters continue to happen with unabated regularity, despite safety oversights imposed on the airlines by regulators. To recognize the operational hazards which we are most exposed, and then develop mitigation has become a vital task for us today. In this regard FOQA has been broadly defined as a program for obtaining and analyzing data recorded in flight recorders to improve flight-crew performance, airlines training program, operating procedures, ATC procedures, aircraft design, maintenance, and operation. NALFOQA software has been successfully used in major airlines like Indian Airlines, Air India, Alliance Air etc., for their day to day Flight Data Recorder (FDR) data analysis as per DGCA mandate. Use of the tool has enabled airlines for reduced insurance premiums. This is one of the greatest achievements of the NALFOQA tool in the civil aviation industry. Today, Major airlines in India and DGCA rely on our software and services for flight safety program.

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